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Inventor(s):

MOHR WERNER (DE); MOEHRMANN KARL-HEINZ (DE); HULBERT PETER ANTHONY (GB); TURKBEYLER ESIN (GB) ;

Applicant(s):

MOHR WERNER (DE); MOEHRMANN KARL-HEINZ (DE); HULBERT PETER ANTHONY (GB); ROKE MANOR RESEARCH (GB); TURKBEYLER ESIN (GB) ;

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ABSTRACT:

In one respect the present invention relates to a method for synchronising radio terminals in a radio communication system, wherein a master radio terminal (M1) transmits first synchronisation signals (pilot), the first synchronisation signals (pilot) are received by at least first and second radio terminals (T1, T2) and are being used to synchronise said first and second radio terminals (T1, T2) to the master radio terminal (M1), the first radio terminal (T1) subsequently transmits data signals (data) and second synchronisation signals (preface) to the second radio terminal (T2), whereby the second radio terminal (T2) can synchronise to the first radio terminal (T1) and detect data signals (data) received.

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(71) Applicant *(for all designated States except US)*: **ROKE MANOR RESEARCH LIMITED** [GB/GB]; Roke Manor, Old Salisbury Lane, Romsey, Hants SO51 OZN (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **HULBERT, Peter, Anthony** [GB/GB]; 48 Wilton Close, Shirely, Southampton, Hampshire SO15 7QH (GB). **MOHR, Werner** [DE/DE]; Josef-Beiser-Str. 12, 81737 Munich (DE). **MOEHRMANN, Karl-Heinz** [DE/DE]; Gottfried-Boehm-Ring 29, 81369 Munich (DE). **TURKBEYLER, Esin** [TR/GB]; 21 Tench Way, Romsey, Hampshire SO51 7RX (GB).

(74) Agent: **HUMPHREY-EVANS, Edward, J.**; Siemens AG, P.O. Box 22 16 34, 80506 München (DE).

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(54) Title: IMPROVEMENTS IN OR RELATING TO A TELECOMMUNICATION SYSTEM

(57) **Abstract:** In one respect the present invention relates to a method for synchronising radio terminals in a radio communication system, wherein a master radio terminal (M1) transmits first synchronisation signals (pilot), the first synchronisation signals (pilot) are received by at least first and second radio terminals (T1, T2) and are being used to synchronise said first and second radio terminals (T1, T2) to the master radio terminal (M1), the first radio terminal (T1) subsequently transmits data signals (data) and second synchronisation signals (preface) to the second radio terminal (T2), whereby the second radio terminal (T2) can synchronise to the first radio terminal (T1) and detect data signals (data) received.to telecommunication systems.

IMPROVEMENTS IN OR RELATING TO A TELECOMMUNICATION SYSTEM

FIELD OF THE INVENTION

The invention relates to telecommunication systems. In one respect the present invention relates to a method for synchronising radio terminals in a radio communication system

BACKGROUND TO THE INVENTION

In radio communication systems, signals are exchanged between radio terminals and radio stations to base stations via a so called radio interface or air interface. These radio terminals are mobile or stationary user terminals; base stations are access stations that are associated with a land based communication network. Examples of known radio communication systems are second generation digital mobile radio communication systems like GSM (Global System for Mobile Communication) based on TDMA (Time Division Multiple Access) and providing data rates up to 100 kbit/s, or third generation digital mobile radio communication systems like UMTS (Universal Mobile Telecommunication System) based on CDMA (Code Division Multiple Access) with data rates up to 2 Mbit/s. With the increasing demand for data transfer with even higher data rates, new wireless local area network (WLAN) systems like Hiperlan/2 or IEEE 802.11 based on OFDM (Orthogonal Frequency Division Multiplex) with data rates up to 20 Mbit/s are under development, enhancing known techniques of wireless local area networks (WLAN) by mobility features known from the above

mentioned mobile radio communication systems. It is anticipated that further future radio developments will utilise Ultra Wideband (UWB) transmission, which will be explained in detail in the following.

Radio communication can be arranged to form so called "Ad hoc Networks". In an ad hoc network, communication may occur directly between any of the user terminals in the network without routing the signals through a central node such as a base station. This is different from mobile radio in which signals are routed using base stations and without the possibilities for direct terminal to terminal communication.

Ultra wideband (UWB) radio, also known as impulse radio, is a technology in which communication is achieved by the transmission and reception of discrete baseband pulses, each pulse having a very short duration, typically less than a nanosecond. The pulses generally have a centre frequency of between 50 MHz and 10 GHz, are very wide (>25% of the centre frequency) in bandwidth and are transmitted with a duty cycle of the order of 1%.

There are several known methods for providing data modulation in impulse communication systems. Two of the more useful methods are pulse position modulation and pulse inversion modulation. In pulse position modulation, the position in time of the pulses in the pulse train is modulated in dependence upon a data signal. For example, to represent the data value "1" a pulse can be shifted forward in time an amount d seconds (d<<1) from its notional regular position in the pulse train, and to represent the value "-1" a pulse may be delayed in time by an amount d seconds from its notional regular position in the pulse train. In pulse inversion modulation, a pulse is transmitted in a "non inverted" fashion to

represent the data value "1" but in an "inverted" fashion if it is to represent the data value "-1" (or vice versa).

If transmitted on a regular basis, an impulse signal would generate a line spectrum which could interfere with the operation of any other radio system having a bandwidth that encompassed the frequency of one of the spectral lines. To mitigate this effect it is known to apply a time hopping code to the pulse train. The time hopping code introduces a pseudo random variation to the time at which each pulse is transmitted within the nominal available period for transmitting the pulse. This modifies the signal, resulting in a spectrum having more lines at closer spacing but of lower power. The line spacing is related to the length of the time hopping code. Multiple access (i.e. a plurality of users operating in the system bandwidth) can be achieved by allocating a unique time hopping code to each user, to create distinct communication channels. Interference between channels will take place only when the time of a received pulse from an interfering transmitter coincides with the time of the received pulse from a wanted transmitter. In theory, by using completely orthogonal time hopping codes such interference could be avoided all together. However, completely orthogonal codes are unusable in practice due to multipath and varying path delays between different users, and so codes with good cross correlation properties over a wide range of time offsets are used instead.

The low duty cycle of the pulse transmission may be viewed as providing a form of spread spectrum.

A further spread spectrum technique may be employed if the transmitter associates a number N (N>1) of pulses with every data bit instead of just a single pulse. This increases the processing gain of the

system and helps further to reduce susceptibility to interference. The nominal timing of each pulse is determined by the time hopping code used, with additional timing adjustments determined by the modulating scheme if pulse position modulation is employed. In the case of pulse inversion modulation, the timing of the pulses will be determined by the time hopping code. In an ideal receiver, a decision variable is obtained as the difference between the output of a filter matched to the "1" signal and output of a filter matched to the "0" signal. In a practical receiver these matched filters are arranged as pulse matched filters arranged to match the anticipated arrival times of each of the pulses in the time hopping code. In the case of pulse inversion modulation a single pulse matched filter provides the difference between the matched filter output for a "1" and for a "0". In the case of pulse position modulation the difference matched filter can be obtained from a single matched filter whose impulse reponse is the time reversal of the pulse as received in the "early" position minus the time reversal of the pulse as received in the "late" position. Either of these can be viewed as a differential pulse matched filter. The final stage in matching to the received data bit is to accumulate the output of the differential pulse matched filter for each of the pulses over the duration of the bit. Modulation may be restricted to the bit level, in which the outputs of the differential pulse matched filter are simply accumulated.

In order for the receiver to demodulate the transmitted data it must synchronise a local time hopping generator to the received sequence of pulses. Because of the use of very narrow, i.e. sub nanosecond, pulses, this synchronisation must be achieved to very high accuracy.

One known synchronisation principle which may be used relates closely to that commonly used for acquiring the code in a conventional direct sequence spread spectrum receiver. According to this principle, a local version of the time hopping code is generated with the help of a local clock. This is used to control a pulse matched filter and aggregate received pulses to an overall correlator output. The period of aggregation in terms of pulses needs to be short enough that there is no modulation of the pulses being sought over this period. The timing of the local clock is shifted in steps until the overall correlator ouput exceeds a threshold. At this point the timing is held. More sophisticated multiple-dwell search approaches could otherwise be employed to improve the performance. An early-late or tau-dither loop can be used to hold the acquired time from then on.

This known approach causes several problems. Firstly, modulation of signals limits the periods of aggregation of pulses. The period is also limited by frequency errors between the transmitter and receiver clocks. Together, these limitations result in a significant mean time to acquire synchronisation. Evaluations have shown that, for a repeating pilot of 10 microseconds, the mean time to acquire synchronisation can be as large as 100 ms. If it is wished to transmit bursts prefaced by a pilot burst then this may need to be of the order of a second's duration to provide high reliability. Given that the data component of the message could take as little as 50 ms to send, this represents an unacceptably large overhead.

OBJECT OF THE INVENTION

One object of the invention is to seek to provide a method for synchronising radio stations for an inter radio station communication.

STATEMENT OF THE INVENTION

In accordance with the first aspect of the invention, there is provided a method for synchronising radio terminals in a radio communication system, wherein a master radio terminal (M1) initially transmits synchronisation signals (pilot); the first radio terminal (T1) subsequently transmits data signals (data) and synchronisation signals (preface) to the second radio terminal (T2), and where said synchronisation signals (pilot) are received by at least first and second radio terminals (T1, T2) and are being used to synchronise said first and second radio terminals to the master radio terminal (M1), and whereby the second radio terminal (T2) can detect the data signals (data) received from the first radio terminal (T1).

BRIEF DESCRIPTION OF THE FIGURES

The invention may be understood more readily, and various other aspects and features of the invention may become apparent from consideration of the following description and the figures as shown in the accompanying drawing sheets, wherein:

Figure 1 shows a first example of a piconet;

Figure 2 shows an example of a UWB Receiver;

Figure 3 show synchronisation signals;

Figures 4 and 5 show second and third receiver structures;

Figures 6a and b show Access Code Based Communications;

Figure 7 shows a Pure Receiver Directed Code;

Figure 8 shows a Split Receiver Directed Code;

Figures 9 shows how Second Signal Reception occurs;

Figures 10 shows a Twin Code Approach;

Figure 11 shows an Inter Terminal Communication;

Figure 12 shows an occurance of a Hidden Terminal Effect;

Figure 13 shows a signalling flow for activation of a radio terminal;

Figure 14 shows resolvable impulse responses.

DETAILED DESCRIPTION OF THE INVENTION

There will now be described, by way of example, the best mode contemplated by the inventors for carrying out the invention. In the following description, numerous specific details are set out in order to provide a complete understanding of the present invention. It will be apparent, however, to those skilled in the art, that the present invention may be put into practice with variations of this specific.

A simple example of an ad hoc system using impulse radio is illustrated in Figure 1. A master radio terminal M1 operates within the network. This master radio terminal M1 transmits, either continously or periodically, a pilot signal consisting of repetitions of a unique time hopping code consisting of a sequence of ultra wideband pulses. Optionally repeats of the sequence may carry pseudo random inversions. The repetitions of the pilot time hopping code could also be binary modulated; by employing a known binary sequence closer spectral lines can be provided for the pilot transmission and in order to permit time to be communicated with an increased period without ambiguity. The pilot

signals are transmitted by the master radio terminal M1 on a physical channel defined by its time hopping code specifically designed for synchronisation of receiving radio terminals T1, T2, i.e. a synchronisation or pilot channel. In an alternative embodiment, the pilot signals are transmitted together with data signals on a signalling channel, i.e. a broadcast channel.

The radio terminals T1, T2 spaced within the operating range of the master radio terminal M1, receive the pilot signals and determine its timing and frequency. Figure 2 shows the architecture of a receiver realised in the radio terminals T1, T2 for the reception of pilot signals.

The signals received by antenna A are first amplified in a low noise amplifier LNA and then applied to a pulse matched filter PMF. This PMF aims to provide an impulse response corresponding to the time reversal of the received pulse shape. A very high speed sampling gate SG samples the output of the pulse matched filter at times determined by a pilot time hopping code generator PTHCG. The samples are then digitised and fed to a digital signal processor DSP. The actual algorithm for synchronisation is implemented in software in the digital signal processor DSP. The DSP then adjusts the timing of the pilot time hopping generator PTHCG as required.

One possible synchronisation algorithm can operate as follows. The DSP arranges for the local pilot time hopping code generator PTHCG to start generating the pilot sequence at an arbitrary time. The outputs of the analogue digital converter ADC are accumulated in the DSP. After either, a period of the whole, or part of the local pilot sequence, the modulus of the accumulator output is compared to a predefined threshold. If the

threshold is exceeded, then synchronisation is deemed to be achieved, at least to a certain degree of reliability. If the threshold is not exceeded, the accumulator is reset and a small time gap is inserted before the pilot time hopping code generator PTHCG continues, either by repeating the whole of the pilot sequence or by continuing from the point where the sequence previously terminated. The process is continued until a detection of the pilot sequence is found. After detection of the pilot sequence a longer correlation is performed on this timing to confirm the finding of the true position. The described procedure is only one of several standard approaches which are equally applicable for receiver synchronisation with a pilot signal.

Following such a synchronisation, all radio terminals T1, T2 in respect of pilot signals from the master radio terminal M1 are mutually synchronised, apart from small errors due to propagation differences.

When a radio terminal T1 intends to transmit data to another radio terminal T2, then in accordance with the invention, it sends its data bursts and additional synchronisation signals. With reference to Figure 3, the synchronisation signals of the radio terminal T1 are realised as a sync burst prefacing each data burst and consist of repititions of a unique time hopping code consisting of a sequence of ultra wideband pulses. In an alternative realisation, the synchronisation signals could also be transmitted in a specific pilot channel pilot as used by the master radio terminal M1.

The structure of the receivers in figure 4 and figure 5 is essentially the same as described with respect to figure 2. The receiver architecture is extended by the inclusion of a preface time hopping code generator

PreTHCG for generating the synchronisation sequence in the preface of the signals received from the other radio terminal. In figure 4, the structure comprises only one sampling gate SG, whereas in figure 5, two sampling gates SG are implemented.

According to the structure in figure 4, the sampling gate SG samples the output of the pulse matched filter PMF at times either determined by the pilot time hopping code generator PTHCG or the preface time hopping code generator PreTHCG. The samples are then digitised and fed to a digital signal processor DSP. The DSP can then sort out which output signal of the ADC corresponds to which, according to signalling received. Given that a synchronisation to the pilot code of the master radio terminal M1 is established, the preface code of the radio terminal T1 will slide past the pilot code in time. If it is determined that both synchronisation codes produce a pulse at the same time or within a margin of error, then the sample is used for both.

In the implementation according to figure 5, two sampling gates SG are realised. Each sampling gate SG is followed by an integrating sample and hold block I-S/H. These allow the accumulation of pulses to be performed in an analogue fashion rather than in the DSP. This realisation could equally be used in the pilot receiver of figure 2. As a result, the two integrations are performed entirely separately. The outputs are then transferred to the ADC at suitable times via a switch S. The transmissions of the codes can be staggered between the master radio terminal M1 and the radio terminals T1, T2 in order to avoid these times coinciding.

In greater detail, this aspect of the present invention can be explained with reference to the example in figure 1. Two radio terminals

T1, T2 are spaced at distances dT1 and dT2 respectively from the master radio terminal M1, and can therefore receive and detect continuously or periodically the pilot signals of the master radio terminal M1 in order to maintain synchronisation to the master radio terminal M1. The pilot signals are transmitted by the master radio terminal M1 with a low-medium power level, for example about 20% of the normal transmit power for normal communications. The radio terminals T1, T2 also listen to at least one other code in a similar way. This other code is that used as a preface to a data burst which may be transmitted by another radio terminal T1 respectively T2 for a direct inter radio terminal communication. The code selected by the radio terminal T1 respectively T2 could be a common network-wide defined code which is always used for such inter radio terminal communications. Alternatively, the code might be specific to that radio terminal, so that any other radio terminal wishing to reach it would always use that code.

If radio terminal T1 transmits to radio terminal T2 using the timing of the established master radio terminal's timing, the signal will arrive at the radio terminal T2 delayed by a time period determined by:

$$(dT1 - dT2 + dT1T2) / c$$

relative to the clock of radio terminal T2, where dT1T2 is the distance between radio terminal T1 and T2, and where c is the speed of light. This potential uncertainty is bounded by the maximum range of the radio terminals T1, T2 to each other and the master radio terminal M1. Thus the searching window for one radio terminal synchronised to the master radio terminal M1 for another will be very small. Thus peer level synchronisation can be performed over a smaller search window. This

means that the length of the synchronisation burst for the inter radio terminal communication mode can also be shorter. Evaluations indicate that about 5 ms could be adequate to provide a 99% acquisition probability.

Once a piconet has been established, peer to peer (or peer to master) communication becomes possible. With all terminals synchronised to their master, the time offset between peers will be upper bounded according to their mutual delay. Thus a short synchronisation preamble before each transmission burst should be adequate to achieve peer to peer sync. If this sync preamble is missed (e.g. because receiver resources were otherwise occupied) it will not be practical to synchronise to the signal or even to detect its presence for that burst. However, each subsequent burst would also have its own sync preamble and should be detected. ARQ (Automatic Repeat Request) protocols can be used to handle the lost bursts.

The use of time hopping code division multiple access (THCDMA) in principle allows many simultaneous peer to peer links to be supported. It is also possible for a suitably equipped receiver to listen to transmissions from more than one transmitter simultaneously. The complexity of the receiver will clearly grow with the number of parallel signals it can receive.

In principle it might be possible to employ a strategy based on the capability of UWB transceivers to receive whilst transmitting. When a particular terminal, *A*, wishes to transmit to another terminal, *B*, it sets its own receiver to look for transmissions to *B* in order to avoid interfering with an existing transmission to *B*. However, as mentioned above, unless

it is listening when the sync preamble is transmitted it will not detect the other transmission. In order to guarantee that any existing transmission would be detected or not interfered with if undetected it would be necessary for *A* to wait for the maximum burst length before transmitting to *B*. This would introduce unacceptable delays. Moreover, if *B* was receiving a signal (e.g. from terminal *D*) and another terminal *C* also wanted to transmit to *B* then they (i.e *A* and *C*) would both detect the end of *D*'s transmission simultaneously and collide. Thus listen-before-transmit is not useful. This is in contrast with normal Carrier Sense Multiple Access (CSMA) where continuous listening *is* practical because there is only one channel.

A further alternative is for the receiving terminal *B* to make a short transmission indicating that it is receiving from *D*. This does not solve the above problem since *A* would still need to be listening to the relevant code at the right time (potentially a full maximum burst length before it wished to transmit). It would have the advantage of solving the hidden terminal effect (where *A* can hear *B* but not *D*).

Following the above discussion we consider the assignment of time hopping codes for reception/transmission. One approach would be for every terminal to use a unique time hopping code for transmission. However every terminal would need to correlate against *all* such time hopping codes continuously in parallel resulting in unacceptable receiver complexity/power consumption. On the other hand the use of a common time hopping code would preclude simultaneous peer to peer links. One solution is to have a common access code. This would be used for the short synchronisation preamble SP. It would then be modulated by data

indicating the intended recipient's address DA followed by the time hopping code which would be used for the remainder of the burst. The receiver would then switch to this time hopping code for reception of the remaining data. The structure is illustrated in figure 6a.

This also shows an alternative, figure 6b, in which the destination address DA is given under the following code FC. The following code FC can either be randomly selected at burst construction time or be associated with the transmitter. In this approach the system may be vulnerable to collisions during the transmission of the access code which all terminals transmit (this is so that receiving terminals only need to be searching for *one* code) In the first option of figure 6 the access code is transmitted throughout the sync preamble SP, and the transmission of the destination address DA and the following code identifier FC. An improvement is obtained with the second option in that the destination address DA is transmitted under the following code. The improvement is likely to be minimal in that the transmissions under the access code will be dominated by the sync preamble SP (the diagram is not to scale). If there is a one to one mapping between transmitter identities and the codes they use then the following code field could simply be the transmitter identity.

An alternative is to use a receiver directed code. In a pure receiver directed code architecture the receiver code is used throughout the burst. The structure illustrated in figure 7 is much simpler:

There is no need for the recipient's address to be transmitted since this is implicitly contained in the code used. Obviously, since there is no following code, there is no field associated with this either. In this case, if two or more terminals transmit to the same receiver they will use the same

code. Unless the start times of the two signals at the receiver are very closely matched, they will not interfere. If they are matched within the period of the sync preamble the receiver can detect an impulse response which is the union of the responses from the two signals. Depending on the relative strengths of the signals there may be a capture effect in which the stronger can be successfully demodulated. If not then both signals will be lost and ARQ will serve to recover the data. If the start times are separated in time by more than the maximum delay uncertainties possible from the available deployment geometries, then they can be resolved as separate signals. The receiver then has the option of selecting one, the other or both of the signals depending on their relative strength and the resources it has available for reception. If the signal timings are separated by more than the period of the sync preamble then the later signal may be ignored provided, again, that most of the multipath structure is isolated from that of the earlier signal. It may be desirable to receive both signals even if the time difference is greater than the preamble period. This could be facilitated by using the structure of figure 8.

In this case two receiver directed codes are provided. These both have a unique mapping to the receiver and are both known by the transmitter. The acquisition circuit searches for Receiver Code 1. When found and finished it assigns a normal receiver to Receiver Code 2. The acquisition circuit continues to search for Receiver Code 1 in case a second transmitter is activated. If this happens a further receiver is assigned to Receiver Code 2 and both signals can be received provided their multipath structure is adequately separated, even though they are using the same code. The procedure is illustrated in figure 9.

An alternative use of the structure would be to arrange for the receiver, upon detecting the second sync preamble SP, to signal to the transmitter that its transmission is interfering with an existing signal and that it should cease. Whilst it is possible to prioritise either signal, in the absence of any signalling capability, priority could be given to the earlier signal since it has already started to transmit a signal using transmission resources. The receiver could incorporate into its transmission the time at which the existing signal will finish. This action could be made conditional on the inability to receive both signals. This approach would overcome the earlier problem with the would-be-transmitter listening in that it would be able to listen at the appropriate time with no overhead. There would also be no hidden terminal effect. If a third transmitter appeared, the receiver could signal to it as well, but this time the receiver would indicate that the signal was third in line and the third transmitter should back off.

If potential collisions of signals to a single receiver are likely to be severe then a two code approach could be adopted as shown in figure 10.

The receiver listens to the receive code and detects the sync preamble SP. It demodulates the transmitter's address TA and maps this to the transmitter code which it then uses to demodulate the remainder of the burst. Alternatively, codes could be selected in a random/pseudo random fashion from an available set. In this case the identity of the transmitter code would also need to be transmitted under the receiver code. In this case only collisions of sync preambles will be unresolvable.

It is to be appreciated that each transmission will be assigned a particular access code: whilst many thousands are possible, it could be

advantageous to have a more limited selection for ease of reference and minimal effect on memory storage/access requirements for radio terminals.

The advantage of such coding is that a terminal could receive many signals which may be destined for its own information or for forwarding in a relay-fashion. In figure 11 a master terminal M1 communicates with terminals T1 and T2: signals 1, 2 and 5 are transmitted with signal 2 being a uni-directional instruction signal which is also relayed to terminal T2. Terminal T1 also communicates with terminal T2 by signal 4 in a bi-directional fashion, whilst signal 3 is relayed by terminal T2 to terminal T3. Nevertheless, this capability could be limited by the processing power of the terminal.

In the following, the activation of a radio terminal and the resolution of a hidden master terminal according to the invention is described with respect to figures 12 to 14.

When a radio terminal T1 is activated it searches all available pilot codes - each associated with a master terminal M1, M2 of an existing piconet PICONET1 resp. PICONET2 (step (1) in figure 13). Because each radio terminal needs to search over all pilot codes there can practically be only a small number, considerably smaller than the number of unique piconets, while there are still enough pilot codes for a sensible reuse pattern. For this reason, associated with each pilot code is an identifier channel, carrying for example general information relating to the identity of the master terminal and/or services provided. The identifier channel is transmitted at lower power than the pilot channel and can be synchronously demodulated against the pilot. The identifier channel is repeated in a time-discontinuous pseudo random fashion so that it can be

received against collisions with transmissions from other master terminals using the same code. There is a one to one mapping between the pilot code and the code used to transmit the identifier channel. Thus a newly activated radio terminal can hear and identify any existing master terminals.

According to information from higher layers, the radio terminal T1 determines whether it should enter the piconet of any of the existing masters terminals T1, T2. If so, it transmits to the selected master terminal M1 using an access code having a one to one mapping to the code used by the master terminal M1 but with a pseudo randomly determined time offset (step (2)). There is at least one access code for each of the available pilot codes, which is used by a radio terminal in response to the reception of the pilot code. The full sets of both codes, the pilot and the access codes, would be known to all terminals. The available offsets are separated by the minimum time needed to avoid ambiguity in range determination. The availability of a set of offsets effectively provides a number of parallel channels for contention access.

The master terminal M1 responds to the access code of the radio terminal T1 by sending a signalling message, corresponding to the terminal's selected time, assigning a communication code for the radio terminal T1 to use for further communication (step (3)). The assigned communication code should be derived from a set related to the pilot code used by the master terminal M1 in order to avoid interference with radio terminals in different piconets using the same code.

The radio terminal T1 then uses the assigned communication code to signal its identity to the master terminal M1 (step (4)). Alternatively the

radio terminal T1 could also have signalled its identity with the original random access.

The master terminal M1 broadcasts the identity and assigned communication code of the radio terminal T1 for the benefit of any other radio terminals of its piconet PICONET1. The master terminal M1 may also broadcast its whole database of identities and assigned communication codes for the benefit of the new radio terminal T1.

If the radio terminal T1 does not hear a master terminal M1 to which it should affiliate, then it itself becomes a master terminal. It transmits a master pilot using a code selected at random from the set of available pilot codes known to it. If the terminal T1 had previously detected one or more master terminals but chose not to affiliate itself with any of them, the terminal T1 selects a pilot code that is not being used by any of these other master terminals. It must transmit the pilot code so that any other radio terminal can hear the master terminal when it comes into range repectively can become active. If this does not happen for a long time then the master may enter a sleep mode to save power. In this mode it would transmit the pilot code intermittently.

In the above described procedure there is the possibility of a so called "hidden terminal" problem in the selection of a suitable pilot code by the master terminals. In this event, two neighbouring master terminals M1, M2 may be unable to receive the pilot code of each other and so the second of these terminals to be activated M2 say, may inadvertetly select the same pilot code already being used by the neighbouring first master terminal M1 say. A new radio terminal T1 may then be activated at a

location where it can receive the pilot code of both master terminals M1 and M2. This exemplary situation is illustrated in figure 12.

The channel impulse response which the radio terminal T1 derives from the two received pilot codes will be the union of the channel impulse response of each of the pilot codes from the two master terminals M1, M2. In practice, if the delay span of the single paths is less than 100 nanoseconds and the pilot period is 100 microseconds, then there is only a 0.1% probability that the two multipath profiles will be unresolvable. Generally, the code hopping sequences should be selected for good auto-correlation properties so that, if the same code is used, there is little interference at time offsets. This is illustrated in figure 14.

Moreover, because of frequency errors within the master terminals, such a situation would only persist for a short period of time. Even if this situation did occur, the pseudo random timing of the identifier bursts would allow the terminal to recognise that two master terminals were transmitting the same pilot code by demodulating two identifier codes.If one of these identifier codes corresponded to a master terminal M1 whose piconet PICONET1 the radio terminal T1 wished to enter, then the radio terminal T1 would wait until the timings of the two pilot transmissions drifted far apart enough to allow the multipath profiles to be resolved. Even if the clocks of the two master terminals M1, M2 happened to be within as little as 0.1 ppm of each other, it would still take only 1 second for the clocks to drift apart by 100 nanoseconds.

According to the invention the radio terminal T1 then sends a special signalling message to its selected first master terminal M1 indicating that the master terminal M1 needs to change its pilot code. The

signalling message could for example include the identity of the selected first master terminal M1, so that the second master terminal M2 would ignore the signalling. With reference to figure 13, the signalling message is sent by the radio terminal T1 together with or included in the access message (step (2)), or alternatively using the assigned communication code (step (6)). The first master terminal M1 then broadcasts a signal to all of associated radio terminals T1, T indicating that it will change its pilot code to a new specific pilot code at a particular time (step (7)). At the appointed time the change takes place in the piconet PICONET1 of the first master terminal M1. The radio terminal T1 can then affiliate to the selected master terminal M1 without conflict. Because of the mapping between access respectively communication codes of the radio terminals and the pilot code of the master terminal, a change of the pilot code of the master terminal will lead to an automatic change of the corresponding access respectively communication codes.

CLAIMS

1. Method for synchronising radio terminals in a radio communication system, wherein

– a master radio terminal (M1) transmits first synchronisation signals (pilot),

– the first synchronisation signals (pilot) are received by at least first and second radio terminals (T1, T2) and are being used to synchronise said first and second radio terminals (T1, T2) to the master radio terminal (M1),

– the first radio terminal (T1) subsequently transmits data signals (data) and second synchronisation signals (preface) to the second radio terminal (T2),

– whereby the second radio terminal (T2) can synchronise to the first radio terminal (T1) and detect data signals (data) received.

2. Method according to claim 1, wherein the first synchronisation signals (pilot) of the master radio terminal (M1) are transmitted in a specific synchronisation channel, or together with data signals (data) in a signalling channel.

3. Method according to claim 1, wherein the second synchronisation signals (preface) of the first radio terminal (T1) are transmitted together with the data signals (data).

4. Method according to any one of the preceding claims, wherein the data is transmitted in radio bursts, the bursts consisting of data signals (data) and synchronisation signals (preamble).

5. Method according to any one of the preceding claims, wherein the synchronisation signals preface a data burst.

6. Method according to any one of the preceding claims, wherein the signals are transmitted using ultra wideband pulses.

7. Method according to any one of the preceding claims, wherein the signals are separated by time hopping codes.

8. Method according to any one of the preceding claims, wherein repititions of the pilot time hopping code are binary modulated with a known binary sequence.

9. Method for transmitting signals in a radio communication system, wherein a first radio terminal (T1) receives identical pilot signals (pilot) transmitted by a first and a second master radio terminal (M1,M2), and transmits a signalling message to the first master radio terminals (M1) indicating that it needs to change its currently used pilot signal (pilot).

10. Method according to claim 9, wherein the signalling message includes information about the use of the pilot signal (pilot) by the second master radio terminal (M2).

11. Method according to claim 9 or 10, wherein the first radio terminal (T1) sends the signalling message together with or included in an access message.

12. Method according to claim 9 or 10, wherein the first radio terminal (T1) sends the signalling message using an assigned communication code.

13. Method for transmitting signals in a radio communication system, wherein a first radio terminal (T1) and a second radio terminal (T2) each transmit a signal burst to a third radio terminal (M1), wherein at least a part of each respective burst is generated by the first (T1) and second (T2) transmitting terminals using an identical code.

14. Method according to claim 13, wherein the identical code is a time hopping code.

15. Method according to claim 13 or 14, wherein the identical code is a receiving terminal specific code.

16. Method according to any of the claims 13 to 15, wherein each respective burst comprises at least two parts, a first part of each burst being generated using the identical code and a second part of each burst being generated using a transmitting terminal specific code.

17. Method according to claim 16, wherein the first part of each signal burst consists of at least a preamble (SP) for synchronising the receiving third radio terminal (M1) to the first (T1) respectively the second radio terminal (T2).

18. Method according to claim 17, wherein the first part of each signal burst also consists of data indicative of the destination address (DA) of the third radio terminal (M1).

19. Method according to claim 17 or 18, wherein the first part of each signal burst also consists of data indicative of the transmitting terminal specific code.

20. Method according to claims 16, wherein the transmitting terminal specific code is a time hopping code.

21. Method according to claim 16, wherein the data indicative of the destination address (DA) is also coded with the transmitting terminal specific code.

22. A radio communication system, comprising;

- a master radio terminal (M1) which is operable to transmit first synchronisation signals (pilot);
- a first radio terminal (T1); and,
- a second radio terminal (T2);

– wherein the first radio terminal (T1) is operable to subsequently transmit data signals (data) and second synchronisation signals (preface) to the second radio terminal (T2), and wherein said first synchronisation signals (pilot) can be received by at least first and second radio terminals (T1, T2) whereby to synchronise said first and second radio terminals (T1, T2) to the master radio terminal (M1), and

– wherein the second radio terminal (T2) can detect data signals (data) received from the first radio terminal (T1).

23. A system according to claim 22, wherein the system is operable to transmit the first synchronisation signals (pilot) of the master radio terminal (M1) in a specific synchronisation channel, or together with data signals (data) in a signalling channel.

24. A system according to claim 23, wherein the system is operable to transmit the second synchronisation signals (preface) of the first radio terminal (T1) together with the data signals (data).

25. A system according to any one of the claims 22-24, wherein the data is transmitted in radio bursts, the bursts consisting of data signals (data) and synchronisation signals (preamble).

26. A system according to any one of claims 22-25, wherein radio transmissions between radio terminals are parrallel.

27. A system according to any one of claims 22-26 wherein at least one radio terminal can support a plurality of transmissions between itself and one or other radio terminals.

28. A system according to any one of claims 22-27 wherein a non-master radio terminal (T1) forwards a message from a second radio terminal (T2) to a third radio terminal (T3).

29. A communication system in which a plurality of radio terminals utilise a synchronisation signal transmitted by a master radio terminal to finely synchronise with the master radio terminal and therebye coarsely synchronise with each other, whereafter one of the plurality of radio terminals utilises another synchronisation signal transmitted by another of the plurality of radio terminals to finely synchronise with the another radio terminal.

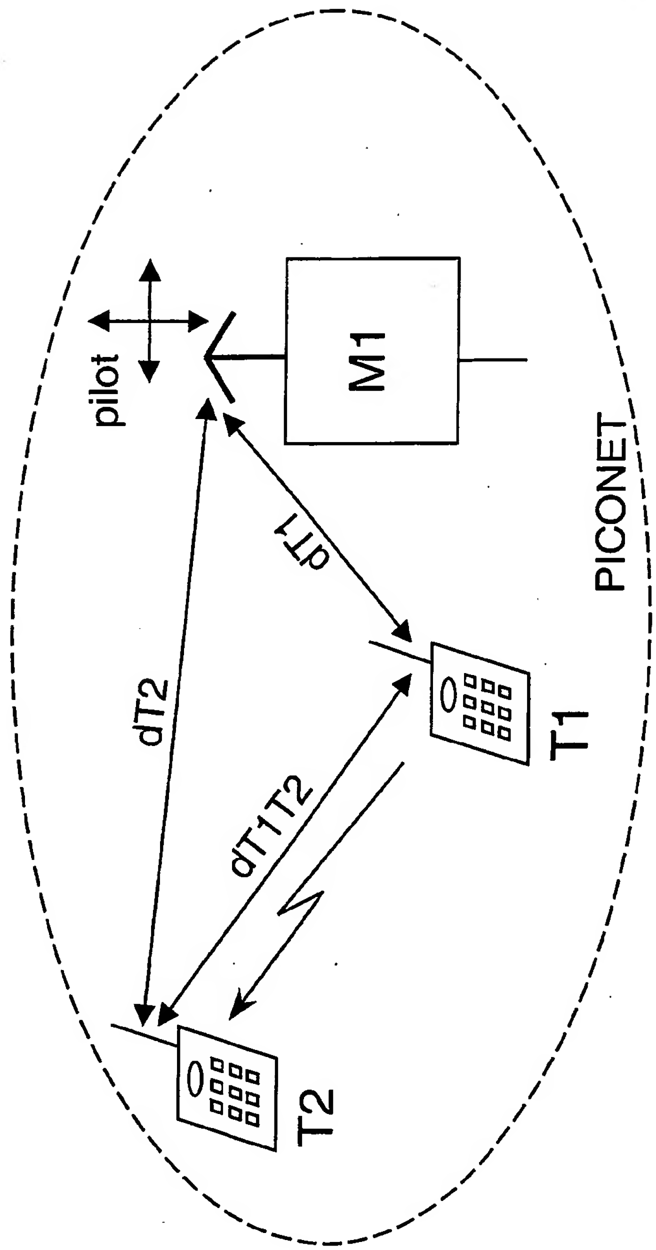


FIG 1

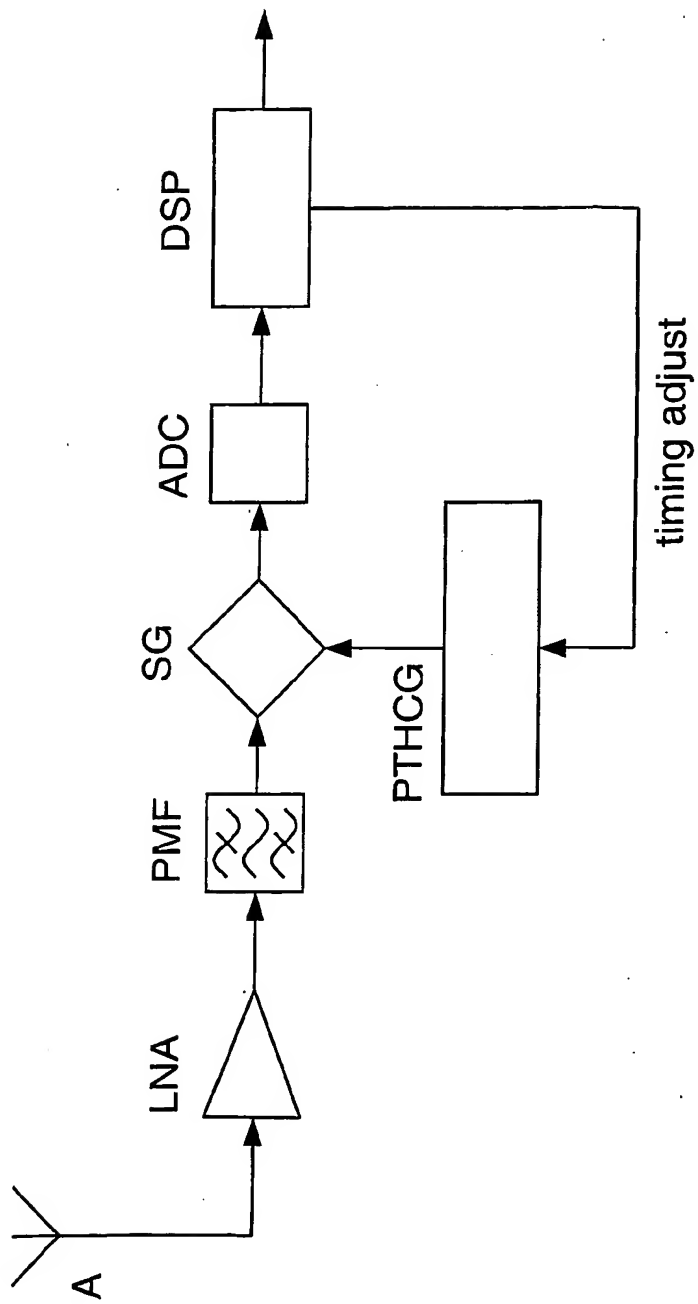


FIG 2

FIG 3

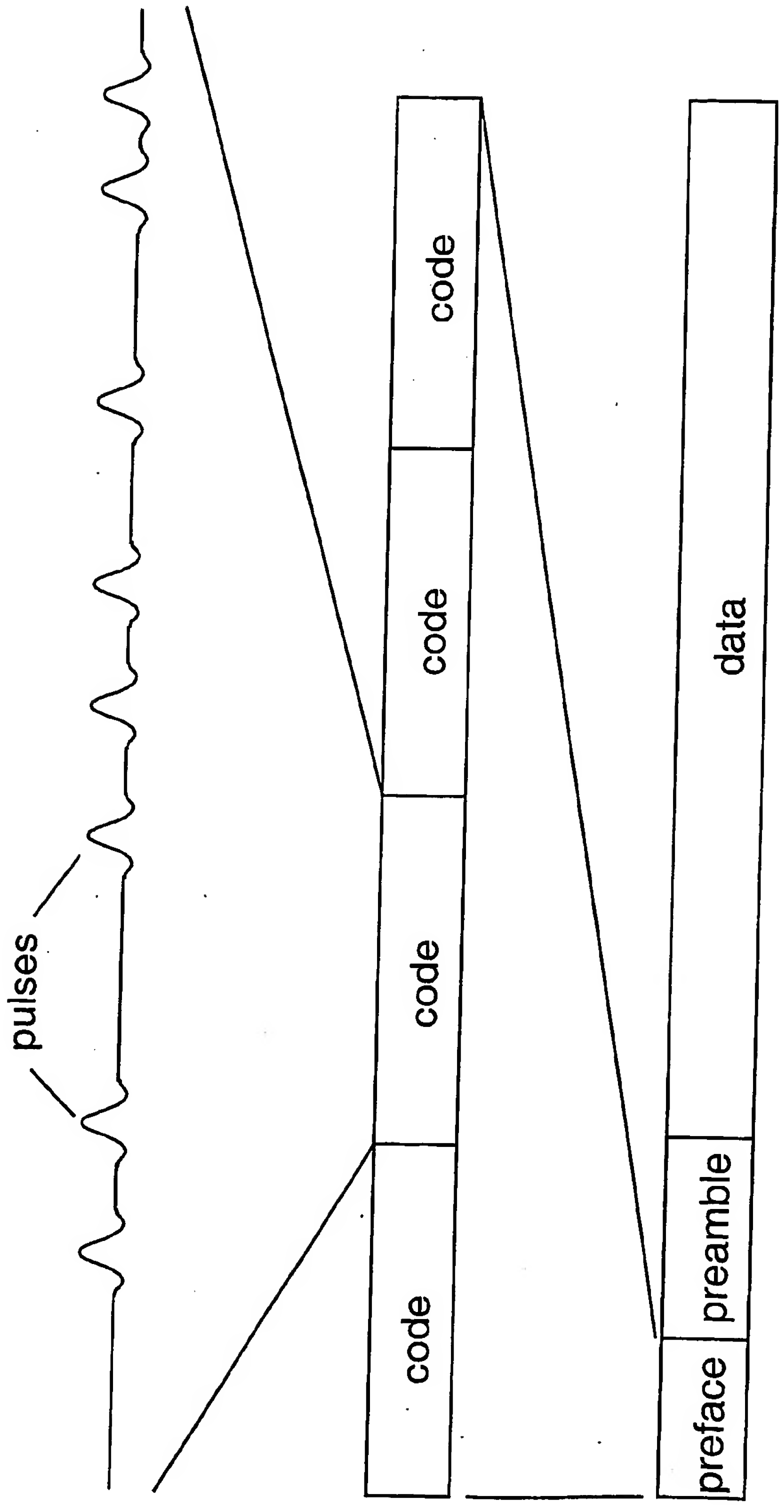


FIG 4

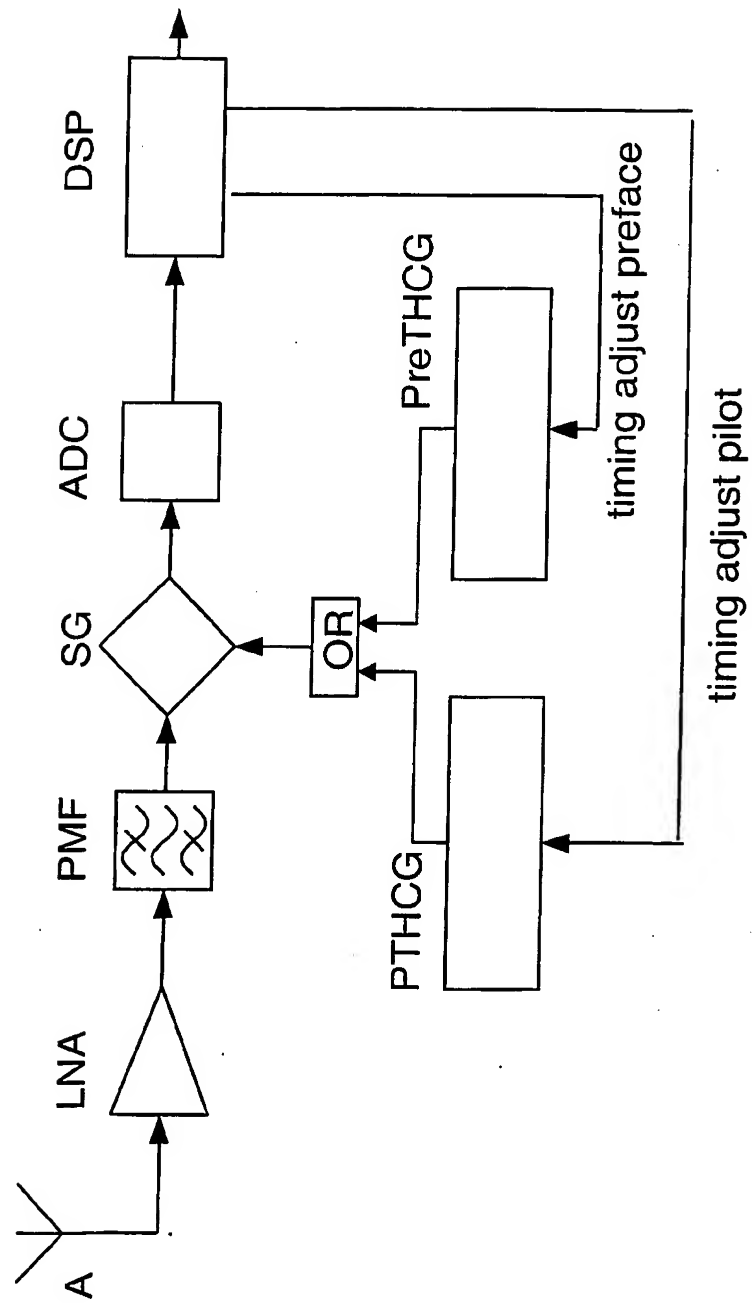

A
LNA
PMF
SG
ADC
DSP
OR
PreTHCG
PTHCG
timing adjust preface
timing adjust pilot

FIG 5

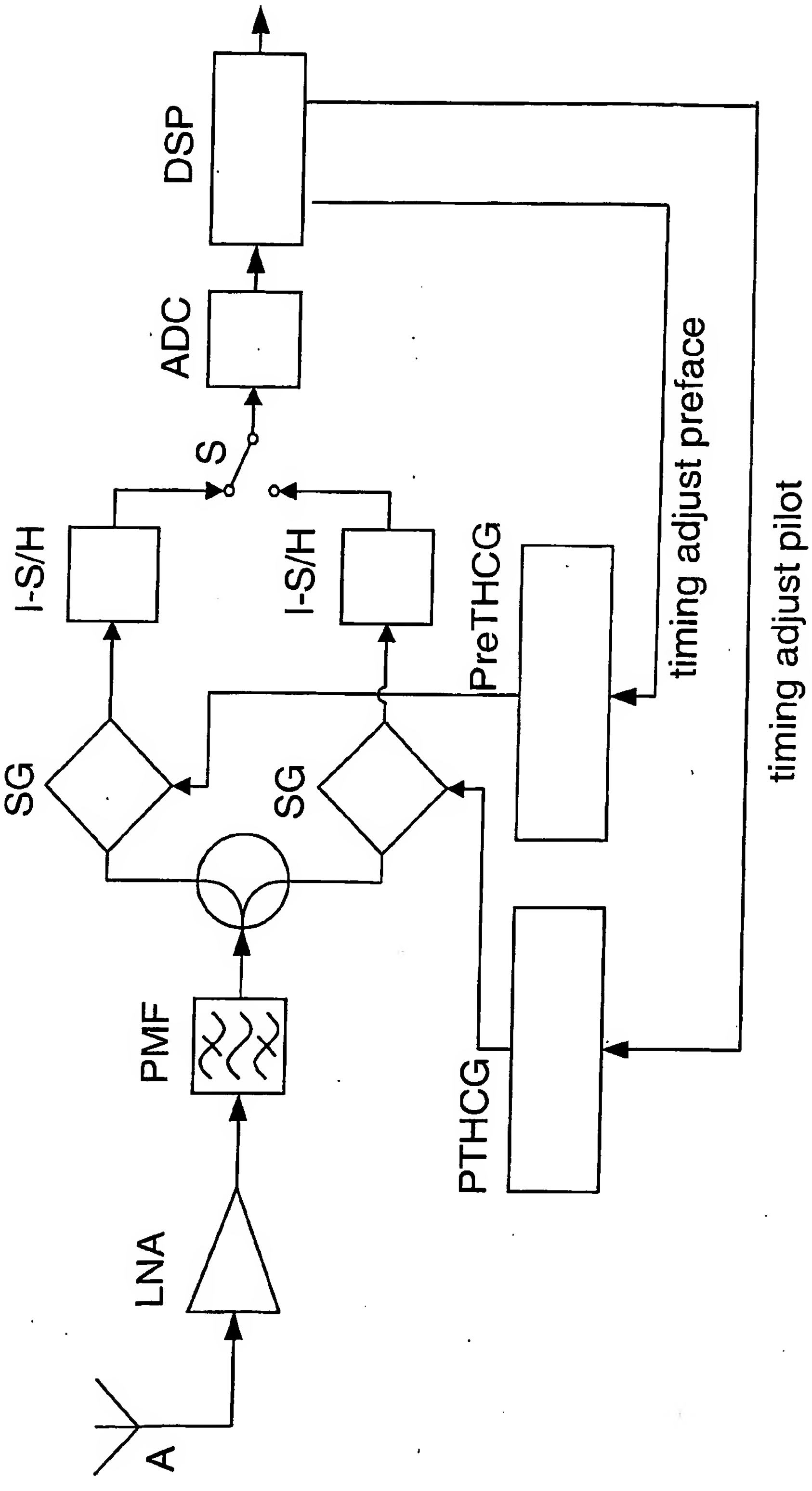

DSP
ADC
S
I-S/H
I-S/H
PreTHCG
timing adjust preface
timing adjust pilot
SG
SG
PMF
PTHCG
LNA
A

FIG 6a

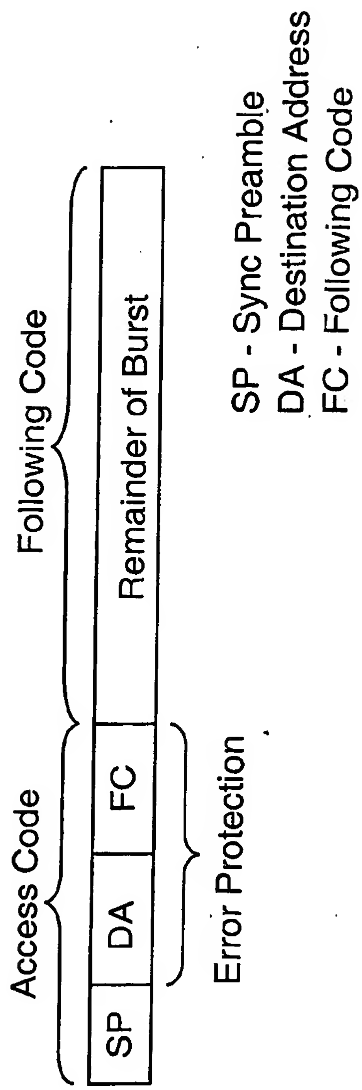
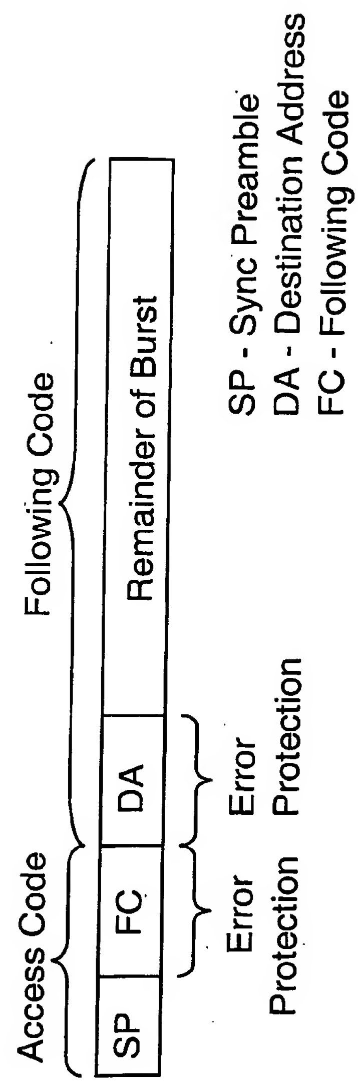

Access Code
Following Code
SP
DA
FC
Remainder of Burst
Error Protection
SP - Sync Preamble
DA - Destination Address
FC - Following Code

FIG 6b


Access Code
Following Code
SP
FC
DA
Remainder of Burst
Error Protection
Error Protection
SP - Sync Preamble
DA - Destination Address
FC - Following Code

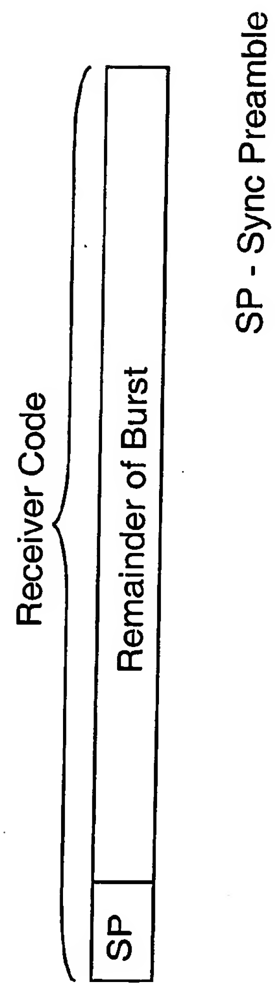

Receiver Code
SP
Remainder of Burst
SP - Sync Preamble

FIG 7

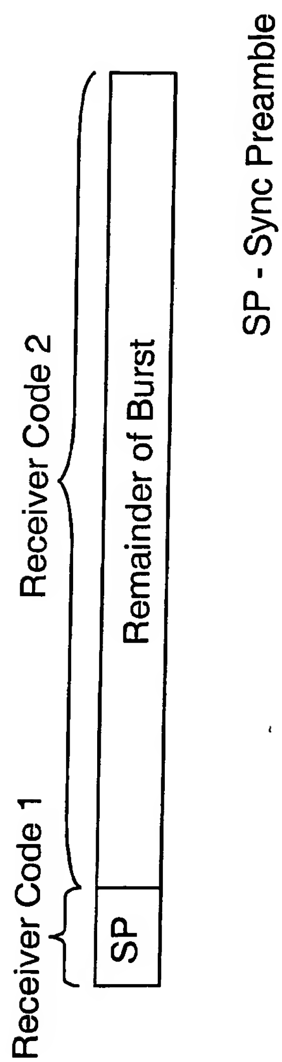
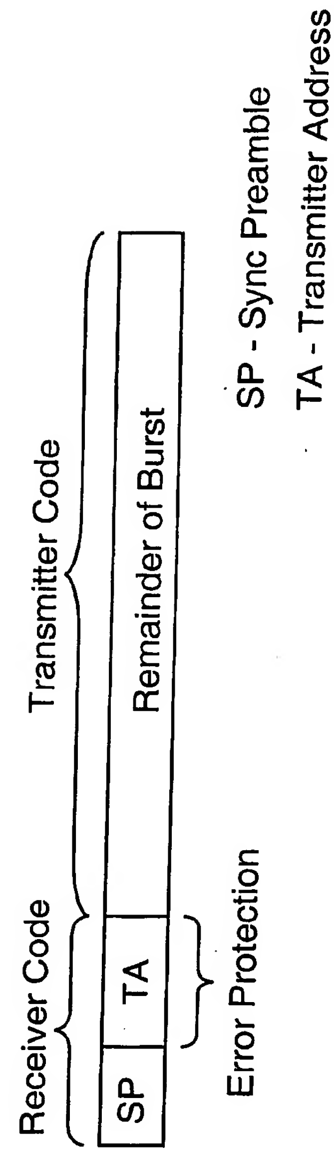

Receiver Code 1
Receiver Code 2
SP
Remainder of Burst
SP - Sync Preamble

FIG 8

FIG 9


Burst 1
Burst 2
Searcher Detects Preamble
Correlator 1 Assigned to Burst 1
Correlator 1 Assigned to Burst 2

FIG 10


Receiver Code
Transmitter Code
SP
TA
Remainder of Burst
Error Protection
SP - Sync Preamble
TA - Transmitter Address

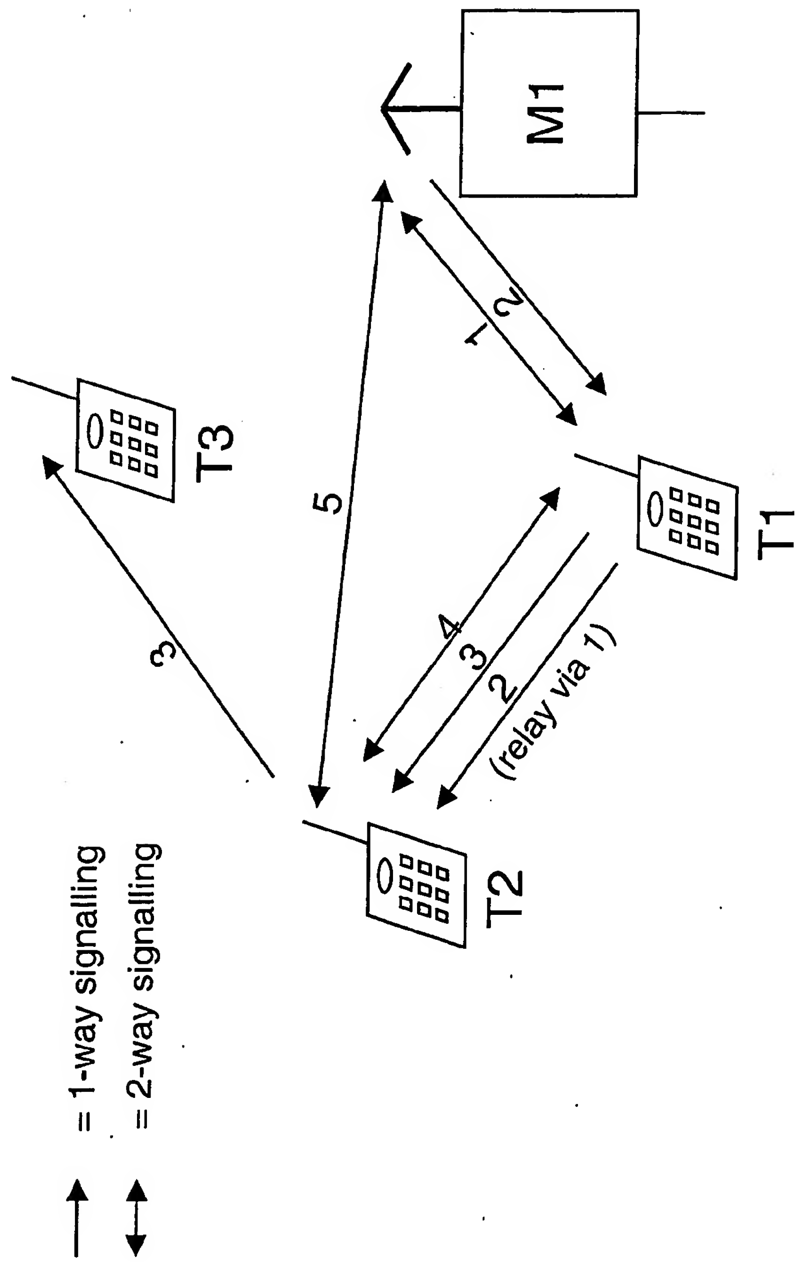

M1
T1
T2
T3
1
2
2
3
3
4
5
(relay via 1)
= 1-way signalling
= 2-way signalling

FIG 11

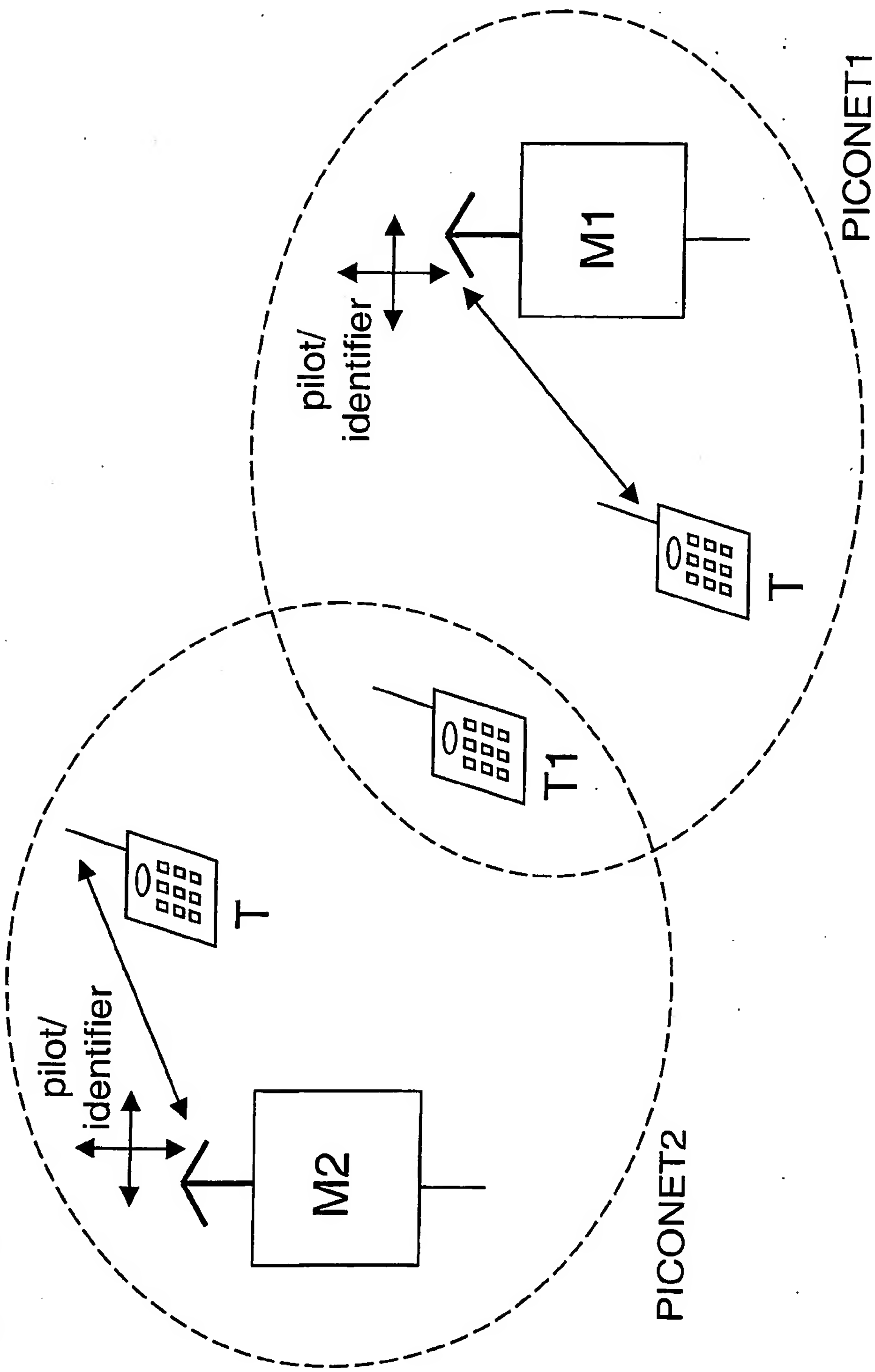
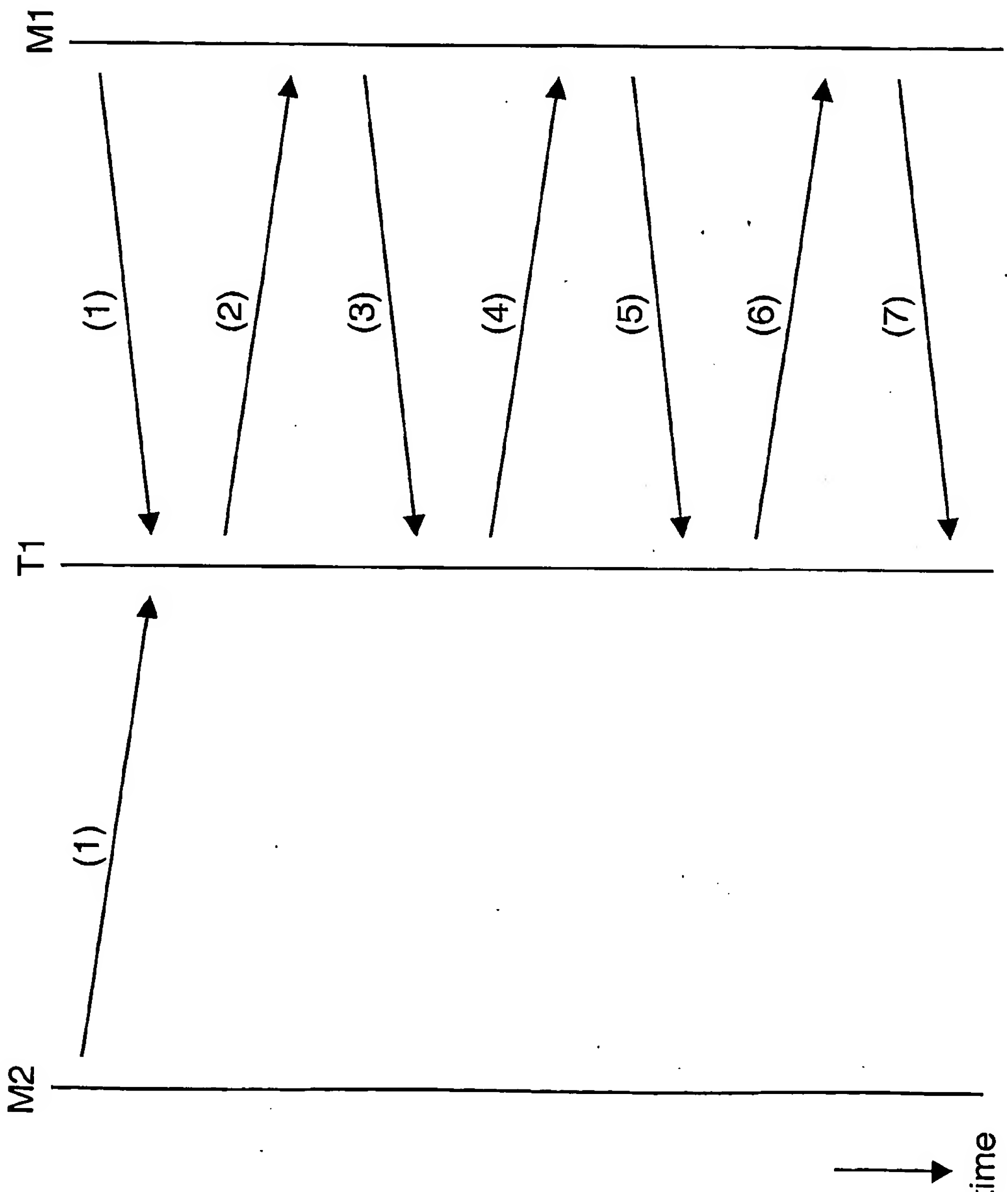

PICONET1
M1
pilot/
identifier
T
T1
T
pilot/
identifier
M2
PICONET2

FIG 12

FIG 13



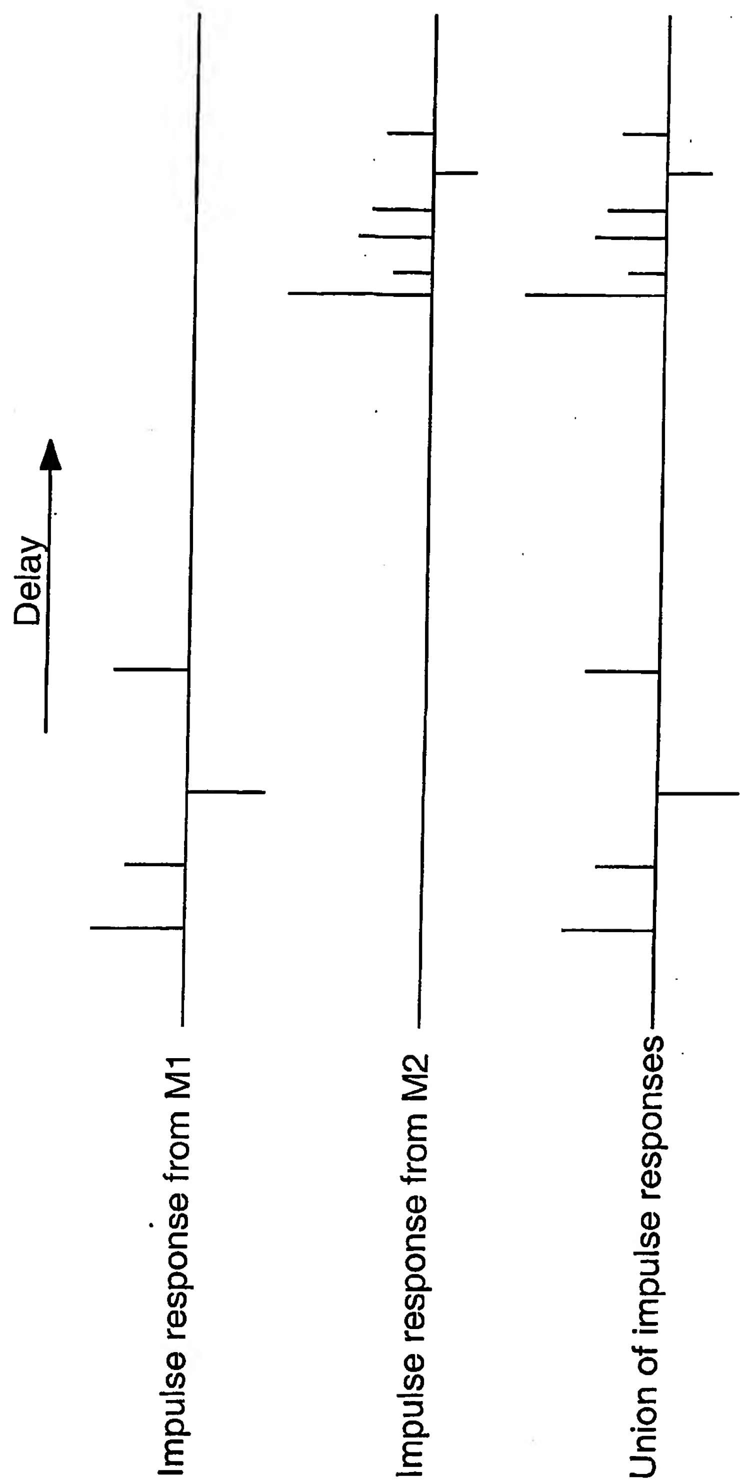

Delay
Impulse response from M1
Impulse response from M2
Union of impulse responses

FIG 14